a volt, but slowly rose again to nearly its original value as the film evaporated. This shows that the electrification was not a temporary one of the glass surface, for that would not have returned to a definite value. Heating the plate by radiation or washing the glass with benzol caused the potential to rise further, but in no case was the potential quite so high as when the plate was first formed. An even more convincing proof that the potential measured was really that of the sodium, was found in the fact that the sensibility of the apparatus was such as would be given by a plate the size of the sodium. If the electrification had been on the whole surface of the glass, the sensibility, on account of the larger surface, would have been at least ten times as great as that observed.

§ 85. The experiments described in this chapter show that (i) when two metals are coated with the same non-conductor, such as wax or glass, their potential is not sensibly different from that of the bare metals in air; (ii) that temperature-variation still takes place, though air be excluded. These results seem to prove that gaseous films play no *essential* part in the phenomenon.

"On the Rotation of Plane of Polarisation of Electric Waves by a Twisted Structure." By JAGADIS CHUNDER BOSE, M.A., D.Sc., Professor of Physical Science, Presidency College, Calcutta. Communicated by Lord RAYLEIGH, F.R.S. Received February 14,—Read March 10, 1898.

In my previous papers* I have given accounts of the double refraction and polarisation of electric waves produced by various crystals and other substances, and also by strained dielectrics. An account was there given of the polarisation apparatus with which the effects were studied. In the present investigation effects had to be studied which were exceedingly feeble. The apparatus had, therefore, to be made of extreme sensitiveness; but the secondary disturbances became at the same time more prominent, and the great difficulty experienced was in getting rid of these disturbances.

In one of my communications I alluded to the fact that these secondary disturbances are to a great extent reduced when the radiators are made small. The advantage of a large radiator is the comparative ease with which the receiver can be adjusted to respond to the waves, but this advantage is more than counterbalanced by the increased difficulty with the stray radiation and other disturbances.

* "On the Polarisation of the Electric Ray by Double-refracting Crystals," 'Journal of the Asiatic Society of Bengal,' May, 1895, and "On a New Electro-polariscope," 'The Electrician,' December 27, 1895.

On the other hand, with small radiators, the difficulty is in the proper adjustment of the receiver. It then becomes necessary to have very exact adjustments of the receiver, both as regards the pressure to which the sensitive spirals are subjected and the E.M.F. acting on the circuit. It is only after some practice that the peculiarity of each receiver is properly understood, when it becomes easy to make the necessary adjustments by which the receiver becomes quite certain in action. For various reasons the radiations emitted by small radiators are more favourable for work requiring great delicacy.

In order that the surface of the radiator should be little affected by the disintegrating action of the sparks, I use a single spark for producing a flash of radiation. There used to be, however, some uncertainty from a discharge occasionally failing to be oscillatory. The cause of this uncertainty is ascribed to the deposit of dust on the sparking surface. For greater certainty of action some observers immerse the radiator in oil. The use of oil is under any circumstances troublesome. This is specially so in polarisation experiments, when the radiator has to be placed in different azimuths. I have for these reasons avoided the oil-immersion arrangement, and have tried to secure certainty of oscillatory discharge without this expedient. Attention was specially paid to the coil and the primary break. A radiator has also been constructed which is found to be extremely efficient. It consists of two platinum beads, each 2 mm. in diameter, separated by 0·3 mm. spark-gap. There is no interposed third ball. This radiator, though kept exposed for days without any protecting cover, was yet found to give rise to a succession of effective discharges without a single failure. I even went so far as to pour a stream of dust on the radiator, in spite of which severe treatment, the sparks were found to be quite effective in giving rise to electric oscillation.

The receiver, too, is perfectly certain in its action, and various degrees of sensitiveness may be given to it. In the following experiments, the sensitiveness had to be very greatly enhanced, and this, as alluded to above, was secured by proper adjustments. The secondary disturbances were got rid of by careful screening. But one serious difficulty was encountered at the very outset, in the failure of the polariser to produce *complete* polarisation. In my first experiments on polarisation (the receiver then used not having been very sensitive), polarisers made of wire gratings were found effective. But in my later experiments with still more sensitive receivers, I found that, owing probably to the want of strict parallelism of the wires and the difficulty of *exactly* crossing the analyser and polariser, it was impossible to produce total extinction of the field. I then made a polariser and analyser by cutting parallel slits out of two

square pieces of thick copper. When the square pieces were adjusted with coincident edges, the analyser and polariser were either exactly parallel or exactly crossed. This improvement enabled me to carry out successfully some of the more delicate experiments. In the present course of investigation the sensitiveness of the receiver had to be raised to a still higher extent, and it was found that the polariser hitherto found efficient failed to produce complete polarisation, so that even when the polariser and the analyser were exactly crossed the non-polarised portion of radiation was of sufficient intensity to produce strong action on the receiver.

In the paper "On the Selective Conductivity exhibited by some Polarising Substances"* I described a book-form of polariser, when an ordinary book was shown to produce polarisation of the transmitted beam, the vibrations parallel to the pages being absorbed, and those at right angles transmitted in a polarised condition. The advantage of this form of polariser was that the extent to which the rays were polarised depends on the thickness of the polarising medium. The rays could thus be completely polarised by giving the medium a sufficient thickness, this thickness being determined by the intensity of the radiation used and the sensitiveness of the receiver. The necessary thickness of the book-polariser may be materially decreased by making the book consist of alternate leaves of paper and tinfoil. The book being then strongly compressed, blocks of suitable size are cut out to form the polariser and the analyser. Each of these blocks is then enclosed in a brass cell, with two circular openings on opposite sides for the passage of radiation. The size of the polariser I use is 6×6 cm., with a thickness of 4·5 cm.; the aperture is 4 cm. in diameter. These polarising cells I find to be quite efficient; when two such cells are crossed, the field is completely extinguished.

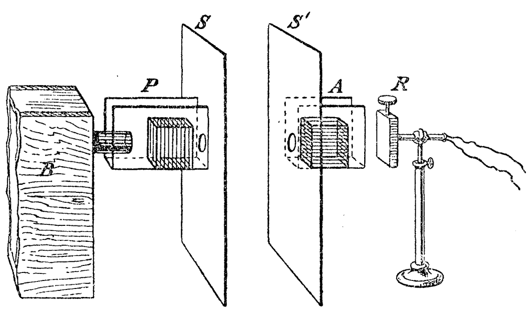

Fig. 1.—Polarisation apparatus. B, the radiating box; P, the polariser; A, the analyser; S, S′, the screens; R, the receiver.

* 'Roy. Proc. Soc.,' vol. 60.

The diagram explains the general arrangement of the apparatus, mounted on an optical bench. The spark gap of the radiator is horizontal. The polariser, with the leaves vertical, is placed on a shelf attached to a screen of thick brass plate 35 × 35 cm. In the centre of the plate there is a circular opening 4 cm. in diameter; this aperture may be varied by a series of diaphragms. There is a second similar screen with a shelf for the analyser, which is placed with the leaves horizontal. Behind the analyser is the receiver.

In the space between the brass plates is placed the substance to be examined. Previous tests are made to see whether all disturbing causes have been removed. The sensitiveness of the receiver is occasionally tested by interposing one's fingers at 45° between the crossed polariser and analyser; this should, by partially restoring the field, produce strong action, provided the receiver is in a fairly sensitive condition.

Care should be taken that there are no metallic masses between the screens, as reflection from metals is found to produce "depolarisation," the rays being then elliptically polarised. The substance to be examined should not, for very delicate experiments, be held by the hand, owing to the disturbing action of the fingers. It is preferable to have the substances supported on stirrups made of thin paper. The above are some of the main precautions to be taken in carrying out the following experiments, where the effects to be detected are very small and therefore likely to be masked unless all disturbing causes are carefully excluded.

I have in a previous communication made mention of the double refracting property of fibrous substances like jute. The field is restored when a bundle of jute is placed at 45° between the crossed polariser and analyser. There is, however, no depolarisation effect when the axis of the bundle is parallel to the direction of the ray.

I now took three similar bundles, A, B, and C, of parallel fibres of jute 10 cm. in length and 4·5 cm. in diameter. No change was made in the bundle A, which was kept as a test one. The bundles B and C were then twisted, B in a right-handed direction and C in a left-handed direction.

The interposition of the untwisted bundle A between the crossed polariser and analyser did not produce any effect, but strong action was produced in the receiver when the bundles, twisted to the right or to the left, were so interposed. It thus appeared as if the twisted structures produced an optical twist of the plane of polarisation.

The further experiments to be described below may be of some interest in connection with the optical rotation produced by liquids. Here two different classes of phenomena may be distinguished:—

(1) The rotation induced by magnetic field; this rotation among

other things is dependent on the direction and intensity of the magnetic field, and is doubled when the ray is reflected back.

(2) The rotation produced by saccharine and other solutions, when the rotation is equal in all directions and simply proportional to the quantity of active substance traversed by the ray; the rotation in this case is neutralised when the ray is reflected back.

The difficulties in the way of explaining the rotation produced by liquids are summarised in the following extract.

"It is, perhaps, not surprising that crystalline substances should, on account of some special molecular arrangement, possess rotatory power, and affect the propagation of light within the mass in a manner depending on the direction of transmission. The loss of this power when the crystalline structure is destroyed, as when quartz is fused, is consequently an event which would be naturally expected, but the possession of it in all directions by fluids and solutions, in which there can not be any special internal arrangement of the mass of the nature of a crystalline structure, is not a thing which one would have been led to expect beforehand. To Faraday it appeared to be a matter of no ordinary difficulty, and I am not aware that any explanation of it has ever been suggested. It is just possible that the light, in traversing a solution in which the molecules are free to move, may, on account of some peculiarity of structure, cause the molecules to take up some special arrangement, so that the fluid becomes as it were polarised by the transmission of the light, in a manner somewhat analogous to that in which a fluid dielectric is polarised in a field of electrostatic force."*

In order to imitate the rotation produced by liquids like sugar solutions, I made small elements or "molecules" of twisted jute, of two varieties, one kind being twisted to the right (positive) and the other twisted to the left (negative). I now interposed a number of, say, the positive variety, end to end, between the crossed polariser and analyser; this produced a restoration of the field. The same was the case with the negative variety. *I now mixed equal numbers of the two varieties, and there was now no restoration of the field, the rotation produced by one variety being counteracted by the opposite rotation produced by the other.*

To get complete neutralisation, it is necessary that the element should be of the same size, and that the two varieties should be twisted (in opposite directions) to the same amount. The experiment was repeated in the following order, to avoid any uncertainty due to the possible variation of the sensitiveness of the receiver. The receiver is adjusted to a particular sensitiveness, and as long as it is not disturbed by the action of radiation, the sensitiveness remains constant. A mixture of opposite elements is first interposed,

* Preston, 'On Light,' 2nd ed., p. 421.

the receiver continuing to remain unaffected. From the mixture of positive and negative varieties, one set, say the negative, is now rapidly withdrawn, and an equal number of positive substituted. The receiver which has not been disturbed since its first adjustment is now found to respond, all the elements conspiring to produce rotation in the same direction. It will be seen that the two experiments are carried out under identical conditions.

In the above, we have electro-optic analogues of two varieties of sugar—dextrose and levulose. There is also the production of an apparently inactive variety by the mixture of two active ones.

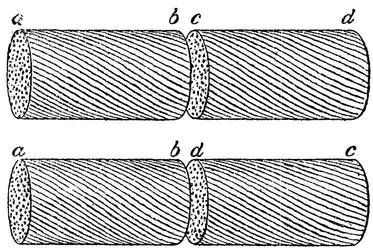

FIG. 2.—Jute elements.

It is to be noted that there is no polarity in the elements, in the sense we use the term in reference to, say, magnetic molecules. *There is nothing to distinguish one end of the jute element from the other end; indeed a right-handed element would appear right-handed when looked at from either end.* It thus happens that if the rotation is determined by the direction of the twist, two molecules of the same variety will always conspire, whether they are arranged as *ab*, *cd*, or, to take the extreme case, as *ab*, *dc* (with the second molecule reversed). The assumption of any particular arrangement of molecules is thus not necessary in explaining the rotation. The average effect produced by a large number of active elements interspersed in an inactive medium will thus be the same in all directions, and proportional to the number of molecules traversed by the ray. *As there is no polarity in the molecule*, a right-handed element will always produce the same kind of rotation, say, to the right of an observer travelling with the ray. The rotation produced when the ray is reversed by reflection will thus be in an opposite direction, and the two rotations will neutralise each other.

But if the molecules exhibit any polarity, that is to say, if the effects produced by the two ends of the same molecule are opposite, the resultant effect produced by a number of such molecules arranged in haphazard directions, will be zero. In order that the effects produced by the molecules may conspire, it is necessary that they should

take up a special arrangement like the disposition of molecules in a magnetised rod. It is seen that in this case the rotations of the direct and the reflected rays are in the same direction, and the resultant rotation is therefore doubled. There is some analogy between the action of such polarised molecules and of substances which, when placed in a magnetic field, rotate the plane of polarisation.

"On the Production of a 'Dark Cross' in the Field of Electromagnetic Radiation." By Jagadis Chunder Bose, M.A., D.Sc., Professor of Physical Science, Presidency College, Calcutta. Communicated by Lord Rayleigh, F.R.S. Received February 14,—Read March 10, 1898.

A circular piece of chilled glass when interposed between crossed nicols produces a dark cross. A similar effect is produced by crystals like salicine where there is a radial disposition of the principal planes.

I have been able to detect a similar phenomenon in the field of electric radiation by the interposition of an artificial structure between the crossed polariser and analyser.

I have in a previous communication described the polarisation produced by the leaves of a book. For the following experiment, a long strip of paper was rolled into a disc. A roll of Morse's tape serves the purpose very well. The diameter of the disc is 14 cm. and its thickness 2 cm. It will be observed that here we have a single axis passing through the centre, and that all planes passing through the centre are principal planes.

The effect produced by the interposition of the structure may be studied by keeping the disc fixed and exploring the different parts of the field by means of the detector; or the detector may be kept fixed (opposite the analyser) and the disc may be moved about so that the different parts of the field may successively be brought to act on the detector. This latter plan was adopted as being simpler in practice.

The arrangement of the apparatus is the same as in fig. 1 of my paper "On the Rotation of Plane of Polarisation of Electric Waves by a Twisted Structure." The polariser is vertical and the analyser horizontal. The paper disc is interposed between the screens with its plane at right angles to the direction of the ray.

The receiver is fixed on the prolongation of the line (which I shall call *the axis*), joining the centres of the polariser and the analyser.

On the supposition that the interposition of the disc produces a dark cross, the arms of the cross (with the particular arrangement

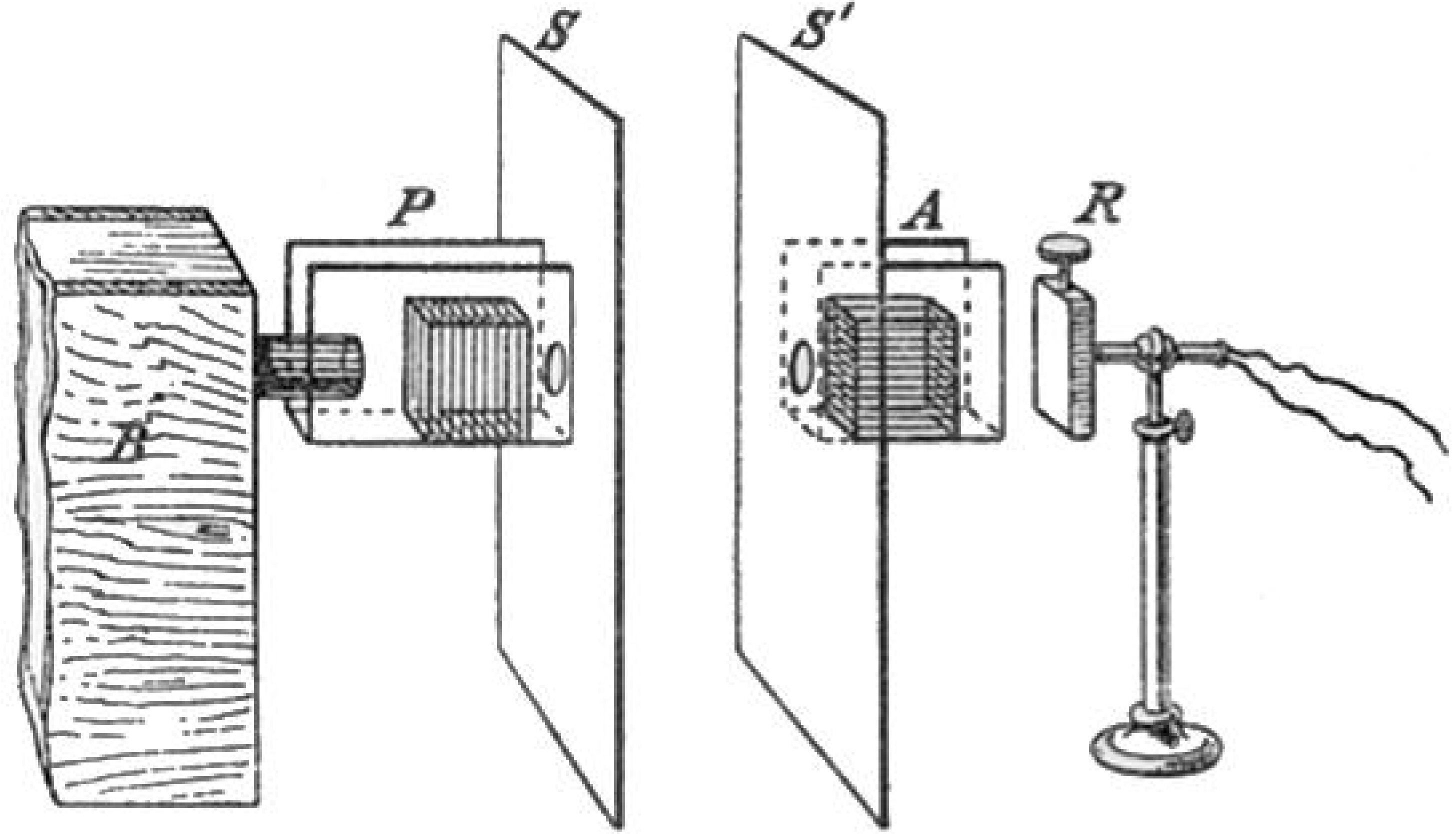

FIG. 1.—Polarisation apparatus. B, the radiating box; P, the polariser; A, the analyser; S, S′, the screens; R, the receiver.

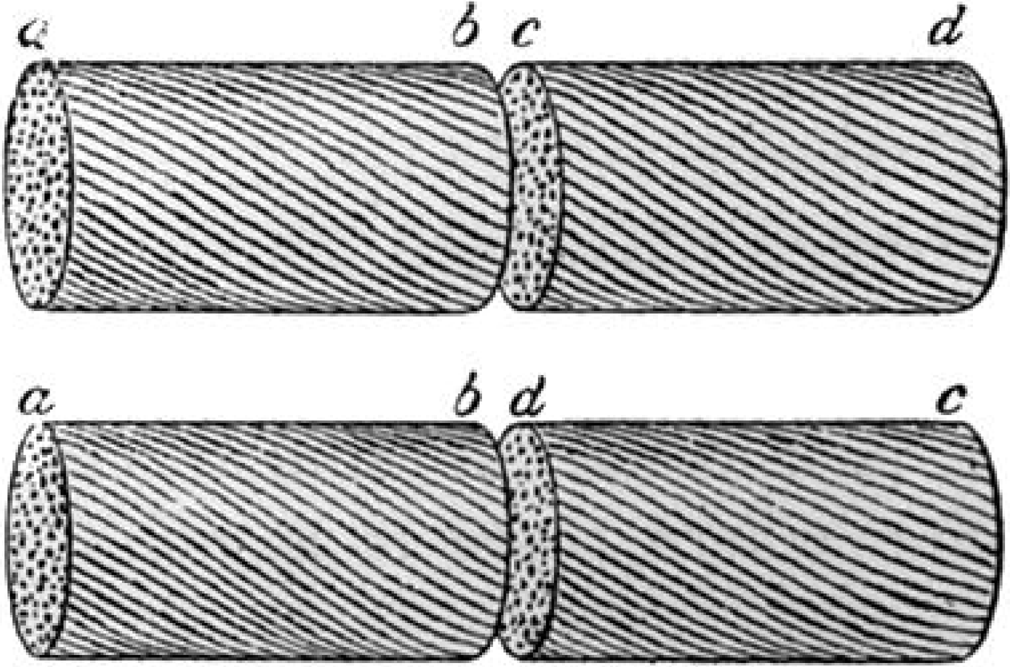

FIG. 2.—Jute elements.